HIGH TEMPERATURE/SOLAR EFFECTS TESTING ON VARIOUS MUNITIONS

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ABSTRACT

The Persian Gulf War produced concerns about the safety and survivability of ammunition being stored in the desert of Southwest Asia (SWA). The temperatures and solar intensity in SWA were reported to be greater than expected. The ammunition was being stockpiled in the only environment available: on the sand and exposed to high temperatures and long daily periods of solar loading. The U.S. Army Combat Systems Test Activity (CSTA) at Aberdeen Proving Ground is addressing these safety concerns by conducting a test program in support of Operation Desert Storm to determine the effects of high temperatures and intense solar loading on various types of ammunition.

The program involves subjecting ammunition to a diurnal cycle simulating the severe temperature, relative humidity, and solar radiation conditions measured during Saudi Arabian summer days. The test items are placed in solar chambers on a bed of sand and exposed for 30-, 60-, and 90-days. Following conditioning, a variety of laboratory and ballistic tests are performed to assess safety and performance.

INTRODUCTION

Exposure of propellants and explosives to high temperatures results in both shortening of useful life and degradation of safety and performance. In an attempt to determine the impact on munitions exposed to the extreme SWA summer, the Predictive Technology Branch at Picatinny Arsenal established the High Temperature Test Program. CSTA was requested to conduct the test in two phases. The first phase was conducted from May 1991 until April 1992 and involved 10 types of ammunition ranging from 60-mm cartridges to 8-inch projectiles. The second phase began in June 1992 and also involves 10 ammunition types including fuzes and anti-tank rockets.

The test requires the utilization of three unique solar chambers, two of which were constructed specifically for the test, to simulate exposure to the SWA desert environment. The diurnal cycle used for this test was developed by Predictive Technology engineers based on actual daily information obtained by the Air Force in Southwest Asia from 1984 to 1989. The diurnal cycle (Figure 1) contains temperature, humidity and solar radiation parameters that represent a worst-case SWA summer day. The diurnal cycle developed was very similar to that of MIL-STD-810E except that the solar loading was slightly lower while temperatures were slightly higher.

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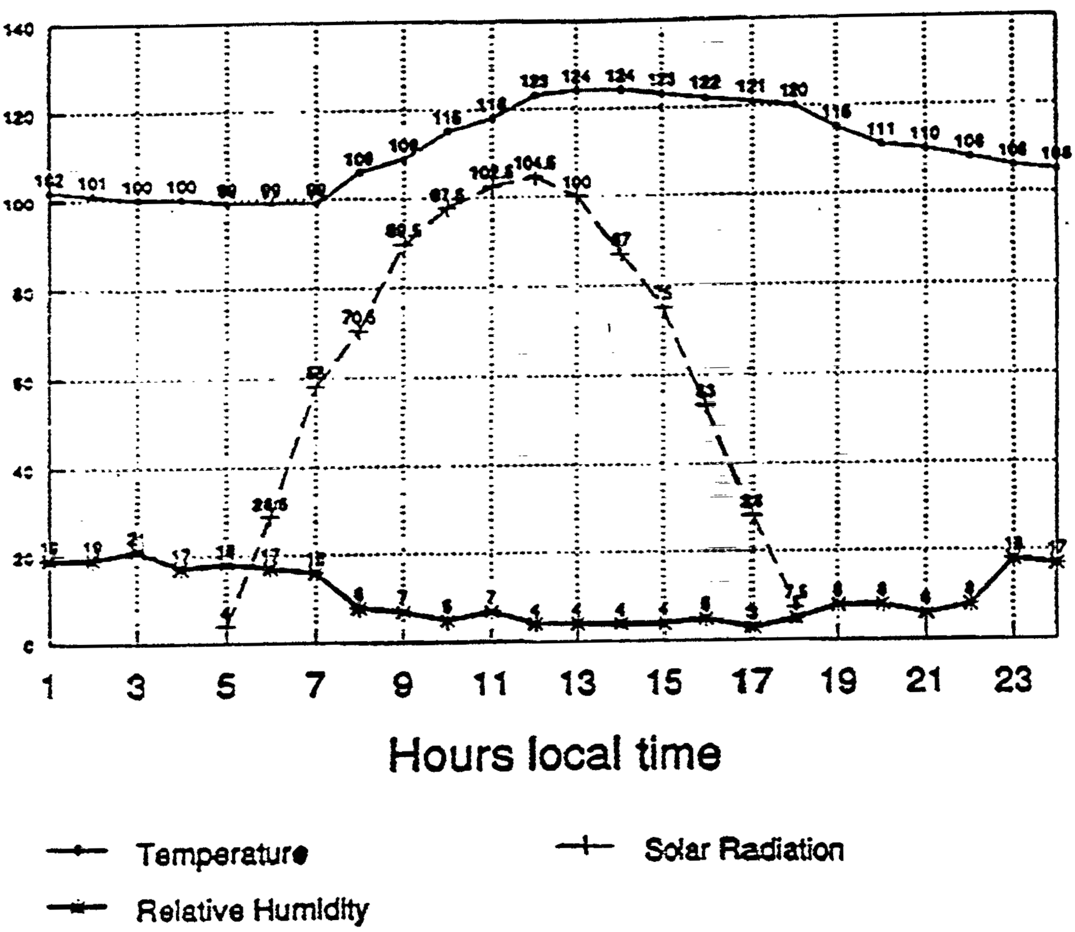
Southwest Asia Profile
Temperature, Solar Radiation
Relative Humidity



Radiation X 10
Temp in degree F, Radiation in W/m^2
Relative Humidity in %

FIGURE 1. Temperature, solar radiation, and relative humidity Southwest Asia profile. Test items were conditioned to this diurnal cycle for 30-, 60-, and 90-day intervals.

TEST ITEMS

The test items used for the High Temperature program and their packaging are as follows:

PHASE I

Cartridge, 60-mm: HE, M720. Each cartridge was in its individual fiber container with eight cartridges per metal can.

Cartridge, 105-mm: HE, M1. Each cartridge was packed in a fiber container with two cartridges per wooden box.

Cartridge, 105-mm: HEAT-T, M456A2. Each cartridge was packed in a metal container with a plastic sleeve surrounding the projectile and a fiber liner around the cartridge case.

Cartridge, 120-mm: APFSDS-T, M829. Each cartridge was packed in a metal container with a foam liner.

Cartridge, 120-mm: APFSDS-T, M829A1. Packaging same as the M829.

Cartridge, 120-mm: HEAT-MP-T, M830. Packaging same as the M829.

Charge, Propelling, 155-mm: M203A1. Each charge was packed in a metal container with a fiber liner.

Projectile, 155-mm: HE, M483A1. Projectiles were unpalletized.

Charge, Propelling, 8-inch: M188A1. Packaging the same as the M203A1.

Projectile, 8-inch: HE, RA, M650. Projectiles were unpalletized.

PHASE II

Fuze, Proximity: M728. Fuzes were packaged eight per metal can.

Fuze, Point Detonating: M739. Packaging same as the M728.

Rocket, 66-mm: HEAT, M72A2. Rockets were packaged in their launchers.

Cartridge, 81-mm: HE, M821. Each cartridge was packaged in a plastic monopack with three cartridges per metal can.

Cartridge, 84-mm: M136 (AT4). Cartridges were packaged in their launchers.

Cartridge, 105-mm: APFSDS-T, M833. Each cartridge was packed in a metal container with a foam liner

Cartridge, 120-mm: HEAT-MP-T, M830. Each cartridge was packed in a metal container with a foam liner.

Charge, Propelling, 155-mm: M4A2. Each charge was packed in a metal container with a fiber liner.

Projectile, 155-mm: Extended Range, DP, M864. Projectiles were unpalletized.

Projectile, 155-mm: AT, M718A1. Projectiles were unpalletized.

TEST CHAMBERS/INSTRUMENTATION

Three chambers are required to simultaneously accommodate all of the ammunition. Combined, the three chambers provide approximately 540 square feet of test area. The two chamber lamp types used are 400 watt lucalox and 1000 watt mercury-vapor with roughly 60% of the lamps in each chamber being the mercury-vapor type. Each lamp is individually controlled and the entire light bank can be raised and lowered to adjust the solar intensity. In addition to solar intensity, both temperature and air flow distribution were measured in each chamber prior to testing. To further simulate the SWA desert environment, the floor of each chamber was covered with sand.

Two rounds of each type were instrumented with thermocouples at locations on the outside and inside of the packaging as well as numerous locations on the outside of the round and in the propellant and explosive (Figure 2). The intent was to gather as much response data as possible to determine not only the maximum surface temperatures but also to be able to determine the heat transfer characteristics within the rounds themselves.

The chamber temperature is controlled using a calibrated micro-processor-multi-looped controller utilizing a type T thermocouple. The internal chamber temperature is maintained within $\pm 2.2\ ^{o}C$ ($\pm 4\ ^{o}F$) throughout the cycle and is measured and recorded at four locations within each chamber. During cycling, the relative humidity is not controlled within ± 5 percent; however, the chamber relative humidity is monitored and recorded. The solar radiation levels are controlled and monitored using a calibrated pyranometer located in the center of each chamber and maintained within $\pm 47\ W/m^2$ ($\pm 14\ Btu/ft^2/h$) during cycling. These analog signal inputs (temperature (both chamber and ammunition), relative humidity, and solar irradiance (voltage)) are recorded using Doric 245 data loggers and MEMTEC 2500 digital recorders. Data is recorded every 30 minutes during cycling.

SAFETY CONSIDERATIONS

Due to the high ammunition temperatures expected on this test, several safety precautions were taken. Initially inert rounds of each type were thermocoupled, subjected to the actual test profile, and the temperature data recorded. This was done to identify maximum temperatures that the different

M830

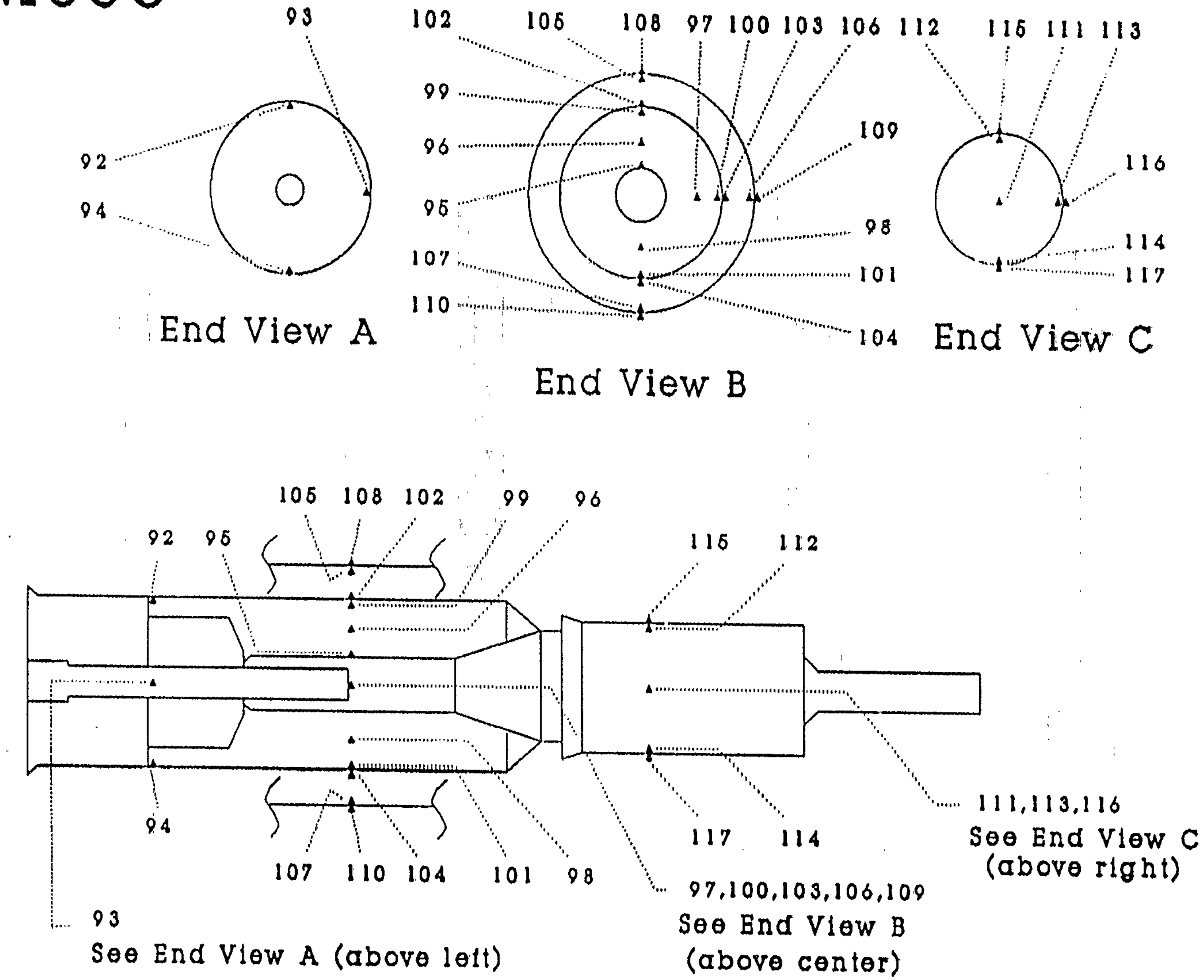


FIGURE 2. Thermocouple location diagram for the M830 cartridge. Thermocouple locations are similar for the other rounds.

areas of the round will reach at stabilization. These temperatures were then compared to the munitions explosive characteristics to determine if there was a potential hazard. Only after the hazard possibilities were assessed did testing on live ammunition take place.

Another safety precaution was linked to the internal temperature of the explosive in specific rounds of ammunition. A thermocouple placed in the high explosive filler (just inside the body wall of these rounds) was hooked to a safety device which would automatically shut down the chamber (temperature and lights) when the critical temperature of 78 ^{o}C (172 ^{o}F) was measured. This temperature was chosen because it is slightly below the melting point for the explosives.

TEST PROCEDURE

The program requires the ammunition to be subjected to 90 continuous days of the temperature-humidity-solar profile. For Phase I, all of the test items except for the M720, M483A1, and M650 were placed horizontally on the sand bed and positioned in one row of one high. The M650 and M483A1 were placed standing on their bases while the M720 rounds were placed vertically, base up, in their metal cans. For Phase II, the fuzes and the M821 were placed vertically in their metal cans while the rest of the items, including the projectiles, were placed horizontally in the chamber. Figure 3 shows the test item setup in the solar chamber. During the test, occasional chamber problems or power interrupts occur which can not be avoided. Once the chambers are brought back on line, the ammunition is re-stabilized to the temperatures that had been measured inside the rounds prior to the downtime, and then test restarted from that point with the time adjusted accordingly.

As a means of determining the aging effects of this environment on the ammunition, the test plans dictated that each type of round be divided into three groups: control rounds (no testing); laboratory rounds (those exposed then subjected to laboratory analysis; and ballistic rounds (those exposed and then fired). The control rounds are further divided into laboratory and ballistic rounds. Certain quantities of each type (laboratory and ballistic) are then removed from the environment at the 30-, 60-, and 90-day intervals of the test to evaluate the cumulative effects of the environment. The laboratory rounds are disassembled and various tests are conducted to determine the chemical composition and sensitivity of the propellant and explosive to see if any changes are occurring. Once the results of the chemical analysis verify that the rounds should be safe to fire, the ballistic tests are conducted for safety and performance.

RESULTS

As expected, different rounds reached different temperatures due to the size of the round, its packaging, and its orientation within the chamber. The following table provides a listing of the highest temperatures measured

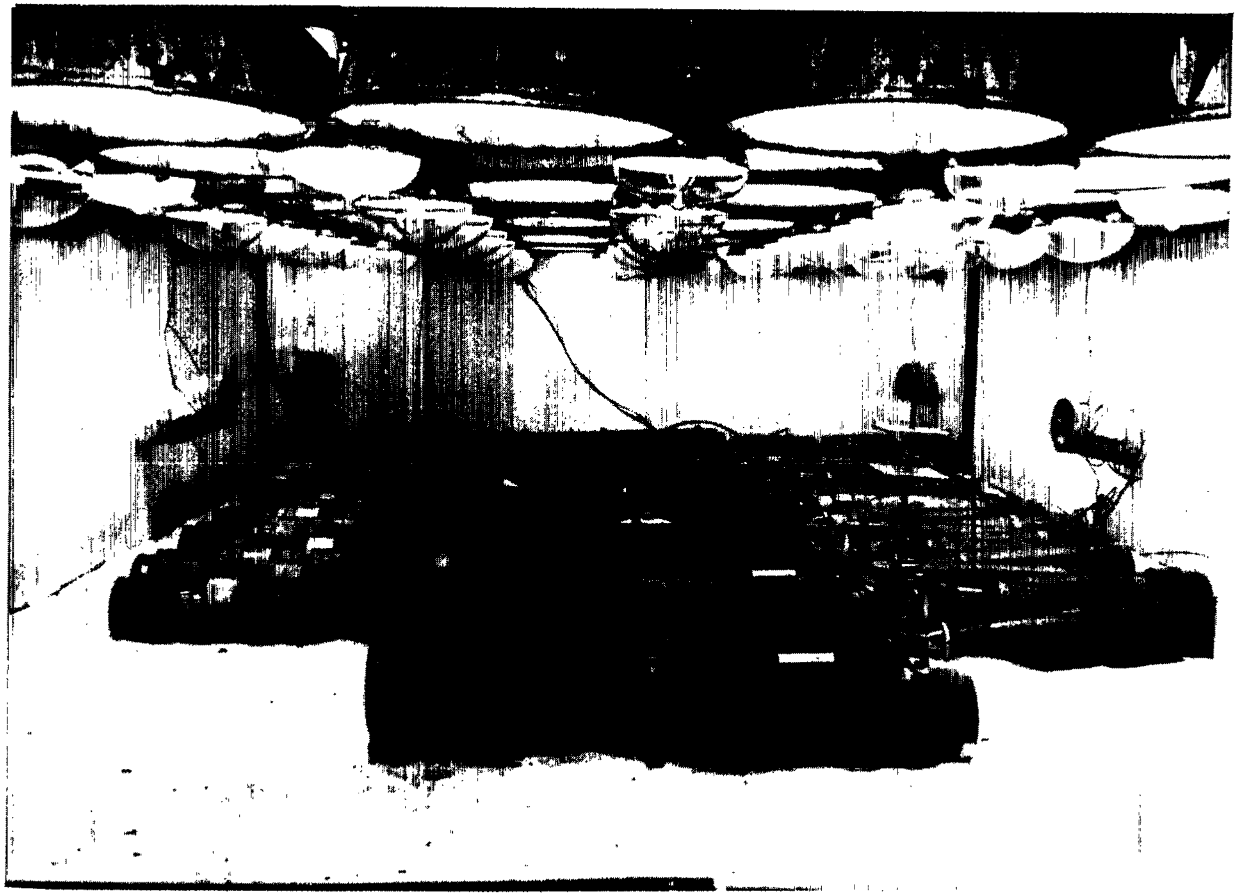


FIGURE 3. Test Items as loaded in the solar conditioning chamber. The solar spectrum is achieved using the Lucalox (larger) lamps and the Mercury Vapor lamps.

within some of the rounds during Phase I of the test. All temperatures are in degrees Fahrenheit.

ROUND TYPE	CONTAINER OUTER SURFACE	ROUND OUTER SURFACE	CORE HIGH EXPLOSIVE	CORE PROPELLANT
M830	205	192	170	180
M829	198	182	NA	155
M456A2	182	164	155	157
M188A1	191	165	NA	145
M203A1	182	169	NA	150
M650	NA	154	148	NA
M483A1	NA	147	148	NA

Laboratory and ballistic results from Phase I are currently being analyzed by the Predictive Technology Branch. Comparisons are being made to acceptance data for the particular lot in question of each round type. If the effect of the high temperature environment produces a noticeable degradation in either chemical or physical properties, then the test results, staggered at 0, 30, 60, and 90 day intervals, should be in the form of a trend. Analysis of this data can be used to predict if and when items will be adversely affected, and to what degree. Thermocouple data is also under analysis to determine how various packaging environments affect the different types of ammunition. Phase II solar conditioning should be completed in Oct 92 with all laboratory and ballistic tests completed by Jan 93.

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